remains, as is admitted, to be experimentally tested), the observed phenomena imply a selective destruction in the one case, and not in the other.

It is not contended that the law of frequency at various ages, adopted in the report, is exact. It is, however, hoped that the approximation is sufficiently exact to give numerical estimates of the quantities measured, which are at least of the same order as the quantities themselves, and for this reason it is hoped that the method adopted may prove useful in other cases.

III. "The Effect of Environment on the Development of Echinoderm Larvæ: an Experimental Inquiry into the Causes of Variation." By H. M. Vernon, B.A. Communicated by Professor J. Burdon Sanderson, F.R.S. Received December 10, 1894.

(From the Zoological Station, Naples.)

(Abstract.)

The conditions of environment under which an organism develops are known to be of considerable influence in the production of variations. It was thought to be of interest to determine by exact measurement the effects which such slight changes in the environmental conditions as might occur naturally would produce in the growth of some organisms. The animal chosen was the larva or pluteus of the sea-urchin *Strongylocentrotus lividus*. These larvæ develop readily from artificial fertilisations, and they can, moreover, be obtained at all times of the year, irrespective of season. The method adopted was to shake pieces of the ovaries and testes of several sea-urchins in small jars of water, and then mix the two liquids. After standing for an hour, portions of the water containing the impregnated ova were poured into jars holding 2 to $3\frac{1}{2}$ litres of sea water, and these were transferred to a large tank of running sea water. The larvæ were generally allowed to develop for eight days, as the aboral and oral arms reach their maximum length in this time. The larvæ were killed by the addition of corrosive sublimate to the water, and were then, after washing in distilled water, preserved in 70 per cent. alcohol. They were mounted in glycerine and measured under the microscope, the body-length, the aboral arm-length, and the oral arm-length being in each case measured. The larvæ were measured in sets of fifties, and the means taken. The aboral and oral arm-lengths were calculated as percentages on the body-length. In all 10,000 larvæ were measured.

The effects of temperature on development were first studied. It

was found that if the ova were placed in water at about 8° or 25° C. for an hour, or even for a minute, at the time of impregnation, the resulting larvæ after eight days development were, on an average, 4·6 per cent. smaller than those impregnated at from 17° to 22°, though all the subsequent conditions of development were identical. If kept at the abnormal temperature for only ten seconds during impregnation, the resulting larvæ were only 1·7 per cent. smaller, probably because the time was too short for all the ova to become impregnated under the abnormal conditions. Differences of temperature during the course of development have in comparison a much slighter influence. Thus larvæ allowed to develop in water at 17° to 22° are only about 2 per cent. larger than those allowed to develop at 15·7° to 17°, or at 22° to 23·7°.

The time of the year when the artificial fertilisations are prepared has a very marked influence on the size of the larvæ. Thus, those obtained in the middle of August are about 20 per cent. smaller than those obtained in April, May, and October, whilst those obtained in June and July are intermediate in size. This is probably due to the comparative immaturity of the ova and spermatozoa in the off-breeding season.

The salinity of the water has a great influence on the development. Larvæ allowed to develop in water containing 50 c.c. of distilled water per litre are 15·6 per cent. larger than those grown under normal conditions, and those in water containing 25 c.c. per litre 9·5 per cent. larger. On the other hand, in water containing 150 c.c. of distilled water per litre they are 4·3 per cent. smaller. In water more concentrated than the normal they remain practically unchanged, but larvæ grown under normal conditions from ova impregnated in concentrated water are 1·6 per cent. larger.

It was thought to be of interest to determine the effects which the various colours of the spectrum have upon development, though these are not conditions of environment which occur in nature. Larvæ allowed to develop in the blue light of copper sulphate solution are 4·5 per cent. smaller than the normal, and those in the violet-blue light of Lyons blue solution 7·4 per cent. smaller. Those grown in the green light of nickel nitrate solution are 4·8 per cent. smaller, and those in red and yellow lights respectively 6·9 per cent. and 8·9 per cent. smaller. The development of the larvæ seems to be but little affected if it is carried out in absolute darkness, the size only being diminished by 1·3 per cent. Larvæ grown in semi-darkness are apparently 2·5 per cent. larger than the normal.

The body-length of the larvæ appears to be uninfluenced by the number of larvæ developing together in a given volume of water, if it be kept below 30,000 per litre. The arm-lengths are, on the other hand, considerably affected. The aboral and oral arm-lengths of

larvæ grown in water containing 4,000 per litre are respectively 13·4 and 15·9 per cent. shorter than of those in water containing 500 per litre; in water containing 17,500 per litre they are 25·9 and 23·3 per cent. shorter, and in water containing over 30,000 per litre 53·0 and 43·2 per cent. shorter.

Certain products of metabolism exert a favourable influence on the developments of the larvæ, and not, as would be naturally expected, a harmful one. Thus larvæ allowed to develop in water containing 1 in 70,400 of uric acid are 12·2 per cent. larger than those grown in ordinary water. It is only when the proportion of uric acid is increased to 1 in 28,000 that an unfavourable influence is exerted, the larvæ being in this case 2·1 per cent. smaller than the normal. In water containing about 1 in 60,000 of urea the larvæ are about 3 per cent. larger. Again, the amount of carbonic acid gas dissolved in the water may be increased by some 18 per cent., so that it is only just insufficient to kill off the larvæ entirely, and yet no diminution in the growth is observed. On the other hand, some of the products of metabolism may produce a considerable decrease in the size of the larvæ, for larvæ grown in water in which other larvæ had previously developed were 7·6 per cent. smaller than the normal.

Thus far the effects of environment on the body-length only of the larvæ have been mentioned. As the arm-lengths were also measured, the effects upon them can also be determined. As a rule, the tissues of the arms seemed to be much more sensitive to environmental conditions than the tissues of the body, and considerable changes were frequently found to occur in them without any obvious cause. The conclusions to be drawn from these measurements are therefore not so unequivocal as from those of the body-length. The most important point established is that one and the same change of environmental condition may frequently produce opposite effects on the arm and body-lengths. Thus the body-lengths of larvæ allowed to develop at temperatures above 22° are about 2 per cent. smaller than of those at about 20°, but the aboral and oral arms are respectively 10·8 per cent. and 8·5 per cent. *longer*. Again, the body-length of larvæ developed in diluted water is on an average increased by 9·1 per cent., but the arm-lengths are *decreased* by 7·7 per cent. and 10·5 per cent., or, as the arm-lengths are percentages on the body-lengths, they are practically not affected at all. Also the arm-lengths are not affected to the same extent by the same change of environmental condition. Thus the ratio between the arm-lengths is 4·3 per cent. higher at temperatures above 22° than at those below 18°.

As the number of measurements made was so large, it was thought to be of interest to subject them to statistical examination. It was found that with the body-length and oral arm-length measurements

the deviations from the average occurred with a frequency indicated by the theoretical law of error. The measurements of the aboral arm-length did not agree so well, possibly owing to dimorphism. The relative probable error of the smaller larvæ was greater than that of the larger ones, in the proportion of 63 to 57. As most of the smaller larvæ were obtained in the summer months, with presumably not quite mature ova, it is probable that the variability in the size, as well as the actual size of the larvæ, is affected by the time of the year in which the fertilisations are made. The variability is also affected by the temperature of development, it reaching a maximum at 18° to 20°. The variability of the organs of echinoderm larvæ is much greater than in the case of higher animals. Thus the probable error of the body-length is 6·1 per cent., of the aboral arm-length 11·3 per cent., and of the oral arm-length 9·4 per cent.

Presents, February 28, 1895.

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